AUTOMATIC SPEAKER VOLUME AND MICROPHONE GAIN CONTROL IN A PORTABLE HANDHELD RADIOTELEPHONE WITH PROXIMITY SENSORS

5 ## Field of the Invention

This invention relates to controlling speaker volume and microphone gain of communications devices, such as portable handheld radiotelephones.

Background of the Invention

A portable handheld radiotelephone (referred to as a "radiotelephone" herein) is conventionally used by holding a built-in speaker and microphone near

10 the user's ear and in close proximity to the user's mouth (collectively referred to as the "user's head" herein), respectively, during audio communication. During the audio communication, however, the user may prefer that the radiotelephone be located some distance away from the user, in a hands-free position.

In today's communication trends, a radiotelephone that integrates more text

15 intensive applications, such as calendar, memo and other text-related applications is often inconvenient and difficult to hold in a conventional manner, because the device requires the user to view a display screen in order to gain access to an application, such as a calendar, while the user attempts to maintain optimum audio

20 communication through the radiotelephone. In a preferred, if unnatural, position, the user holds the radiotelephone display screen near the user's eyes and manually adjusts a speaker volume control and/or microphone gain control to maintain audio communication with the radiotelephone in this position. Presently, speaker volume and microphone gain control are adjusted using manual switches, which

25 are often inconvenient to reach and use. This arrangement may also cause damage

to the user's ear, if the user forgets to return the manual switches to normal levels, when the user once again holds the radiotelephone speaker near the user's ear.
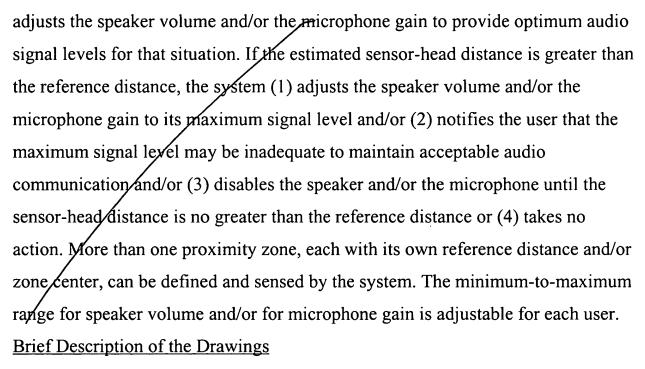
What is needed is an automatic speaker volume control system and/or microphone gain control system, based on sensing the radiotelephone position relative to the user or the user's head, where the user need not manually intervene to control speaker volume and/or microphone gain. Preferably, more than one sensing device and/or more than one type of sensing device should be optionally usable in order to reduce the possibility of error in relative position. Preferably, the system should distinguish between a proximity zone surrounding the user or user's head, in which the speaker volume and/or microphone gain can be continuously adjusted to provide optimum audio levels, and an outer zone where only maximum speaker volume and/or microphone gain are suitable for maintaining audio communication.

Summary of the Invention

These needs are met by the invention, which provides one or more distance sensors on a radiotelephone to estimate a distance between the sensor and some portion of the user or user's head. The sensors are usable individually. Preferably, two or more such sensors are used together to provide an improved estimate of the sensor-user distance. The distance sensors include, but are not limited to, an infrared sensor, a photoelectric sensor, a sound reflection sensor, a capacitive sensor, and a temperature sensor, and a given sensor type may be provided at more than one location on the radiotelephone to account for the possibility that the radiotelephone may be placed in a rotated angular orientation relative to the user or user's head. A sensor estimates a sensor-head distance and compares this distance with a reference distance that defines a proximity zone surrounding the user's head. If the estimated sensor-head distance is no greater than the reference distance, the system automatically (e.g., electronically and/or mechanically)

adjusts the speaker volume and/or the microphone gain to provide optimum audio signal levels for that situation. If the estimated sensor-head distance is greater than the reference distance, the system (1) adjusts the speaker volume and/or the microphone gain to its maximum signal level and/or (2) notifies the user that the maximum signal level may be inadequate to maintain acceptable audio communication and/or (3) disables the speaker and/or the microphone until the sensor-head distance is no greater than the reference distance or (4) takes no action. More than one proximity zone, each with its own reference distance and/or zone center, can be defined and sensed by the system. The minimum-to-maximum range for speaker volume and/or for microphone gain is adjustable for each user.

Brief Description of the Drawings

Figures 1A, 1B and 1C are perspective views of a radiotelephone, illustrating an ear position mode, a frontal position mode and a hands-free mode of operation.

Figure 2 illustrates suitable locations for a sensor.

Figure 3 graphically illustrates an approximate relationship between an intensity of a reflected signal and a distance between a signal source-sensor and a signal-reflecting object.

Figure 4 schematically illustrates use of a capacitive proximity sensor.

Figure 5 schematically illustrates use of temperature sensing to estimate distance and a field of view of the sensor.

Figure 6 graphically illustrates variation of sensed temperature with the fraction F of sensor field of view occupied by a warm or hot object.

Figure 7 is a flow chart of a method for practising the invention.

Figure 8 schematically illustrates a conventional radiotelephone incorporating the invention.

Figures 9 and 10 graphically illustrate suitable variations of speaker volume and microphone gain with estimated user distance d.

Description of Best Modes of the Invention

Figure 1A illustrates an ear-position mode of handheld use of a radiotelephone 11, in which a user 13 holds the radiotelephone so that the speaker 15 and microphone 17 of the device are positioned adjacent to the user's mouth 21 and to the user's ear 23, respectively. Here, the audio signal levels for the speaker 15 and microphone 17 may be adjusted by the user by varying the ear-speaker distance, using audio feedback that is unconsciously implemented by the user.

Figure 1B illustrates a frontal position mode of handheld use of a radiotelephone 11, in which a user holds the radiotelephone in front of the user's face. Here, the user may need to manually adjust the speaker volume and/or microphone gain to provide adequate levels of audio signals.

Figure 1C illustrates a hands-free mode of use of the radiotelephone 11, in which the device is often set down or otherwise positioned at a selected angular orientation and distance d relative to the user 13, leaving the user's hands free to pursue other activities. In this mode of use, it would be necessary to manually adjust the speaker volume and/or microphone gain so that adequate audio signal levels are provided for the user 13. If the user 13 moves relative to the radiotelephone 11 during the audio communication, it would be necessary to manually readjust the audio signal levels, one or more times as the user moves around or shifts location or orientation relative to the radiotelephone. Alternatively, a separable loudspeaker might be provided for the user 13.

The invention, illustrated in one embodiment in Figure 2, provides the radiotelephone with a distance sensing and audio signal level adjustment system 31. The system 31 provides one or (preferably) more signal sources 32-i and associated signal sensors 33-i (i = 1, 2, ...) at selected locations and angular

orientations on a radiotelephone 34, in order to estimate a distance d1 between a user's head 35 and one or more of the signal sources 32-1 and/or to estimate a distance d2 between a user's head 35 and one or more signal sensors 33-1. Preferably, a signal source 32-i and associated signal sensor 33-i are located

5   adjacent to or contiguous to each other on the housing of the radiotelephone 34 so that the distance d1 from the signal source 32-i to the user 35 (e.g., user's head or upper body portion) is substantially equal to the distance d2 from the user 35 to the associated signal sensor 33-i. However, the distances d1 and d2 may be substantially different from each other, if appropriate compensation is provided in

10   the signal analysis. The radiotelephone system 31 may be used in a hands-free mode of operation, or may be used in the ear-position mode or the frontal position mode illustrated in Figures 1A, 1B and 1C, among other positions.

A signal source 32-i and associated signal sensor 33-i may be located at or near a corner of the radiotelephone housing 34 (i = 1, 2 in Figure 2), may be

15   located along an edge of the housing (i = 3), may be located on a relatively flat exposed surface of the housing (i = 4), or may be located on a surface of the housing 34 that is not shown in Figure 2. It is preferable to provide two or more signal sources 32-i and two or more associated signal sensors 33-i on the radiotelephone housing 34 in order to provide for arbitrary angular orientation of

20   the radiotelephone system 31 relative to the user 35.

Each signal source 32-i and each associated signal sensor 33-i will have a characteristic variation of signal intensity or signal sensitivity with an incidence angle ϕ, measured about a central direction. These variations with incidence angle should be accounted for in placing and orienting the signal sources 32-i and signal

25   sensors 33-i on the radiotelephone housing 34.

A suitable signal sensor may rely upon emission, reflection and receipt of infrared or radiowave signals (frequencies f = 10^9 Hz - 4×10^{14} Hz), photoelectric

signals ($f = 4 \times 10^{14}$ Hz - 10^{15} Hz), or sound signals ($f = 200$ Hz - 10^{4} Hz), may rely upon a capacitive proximity sensor (capacitance changes monotonically with distance of the sensor from the body of a nearby object, such as a human being), and/or may rely upon receipt of signals representing temperature of an emitting object, such as the user's exposed head.

Where an infrared, radiowave, photoelectric or sound signal is received and sensed, this signal preferably has a signature (e.g., a special combination or sequence of frequencies) or is emitted only during a special gating time interval (analogous to radar signals) to distinguish this signal from background signals. A capacitive proximity sensor and a temperature sensor do not require emission of a standard electrical signal in order to sense proximity of the object.

The signal intensity I(d) for a received infrared, radiowave, photoelectric and sound signal reflected from a reflecting surface will decrease with distance d (= d1= d2) to the reflecting surface approximately as

$$I(d) = (d + d0)^{-m} \exp\{-\alpha d\}, \tag{1}$$

where m is a selected positive number (e.g., m = 2-4), d0 is a selected non-negative distance and α is a selected non-negative absorption coefficient. The choices d0 = 0, m = 2 and α = 0 reproduce the well known inverse square law. Choice of an absorption parameter value $\alpha > 0$ allows one to account for partial absorption of the signal by an ambient medium, where α may vary with wavelength or frequency of the signal. Figure 3 graphically and approximately illustrates variation of intensity I(d) with distance d for such signals. The parameters d0, m and/or α may vary with the type of signal used, with the angular orientation of the reflecting surface relative to the signal source and signal sensor, and/or with the type of reflecting surface.

Figure 4 illustrates one version of a capacitive proximity sensor 41, in which first and second electrically conducting plates, 43A and 43B, are separated or insulated from each other, with a positive voltage or charge and a negative voltage or charge applied to the first plate and to the second plate, respectively. Electrical field lines 45-i develop between the two plates, 43A and 43B, with each line having a source on one plate and a sink or destination on the other plate. The ambient medium (e.g., air or another fluid) between the two plates serves as a dielectric for the field lines 45-i. The two plates, 43A and 43B, are connected to a resonant oscillatory circuit 47, having a form well known in the art, with circuit parameters chosen so that, when the field lines are undisturbed, the system oscillates at a reference frequency f0. When an object OBJ is moved through a portion of space covered by some of the field lines 45-i, a number N of these field lines are disturbed. The number N of disturbed field lines increases monotonically as the distance d(OBJ,plate) of the object OBJ from a plane defined by one or both of the plates decreases. As more and more of the field lines are disturbed, corresponding to decrease of the distance d(OBJ,plate), the circuit oscillatory frequency f moves further and further from its reference frequency, and the magnitude |f - f0| is a measure of the distance d(OBJ,plate). This form of capacitive proximity sensor uses an oscillatory signal produced within the circuit 47, including the field lines 45-i, but does not require generation and transmission of an electromagnetic signal from this sensor to the object whose proximity is being sensed.

A temperature sensor does not require a signal generator; the signal generator is the object surface itself. If the object is a head of a living human being, the temperature T sensed will be relatively high (e.g., T = 32-36 °C), if the temperature sensor is located reasonably close to the head and will be substantially lower (e.g., T = 10-25 °C), if the object is an inanimate object in the interior of a

building. A temperature sensor will have a certain angular field of view FOV, as illustrated in Figure 5. If the FOV includes only a relatively warm object, such as a human head, the sensed temperature T1 will be relatively high. As the orientation of the temperature sensor changes and a greater and greater fraction F of the

5 sensor's FOV is taken up with one or more inanimate (and cooler) objects, the sensed temperature T will decrease toward a lower temperature T2, as graphically illustrated in Figure 6.

Figure 7 is a flow chart of a method for practising the invention. In step 61, a system determines if a particular radiotelephone is activated for use. A

10 radiotelephone is "activated for use" if one or more selected functions on the device is being used presently. These selected functions may include one or more of: (1) radiotelephone voice activation, (2) entry of numbers or other alphanumeric information using the keypad and (3) any other function that indicates that the radiotelephone is being readied for use in a conversational mode.

15 If the answer to the query in step 61 is "no", the system takes no further action, in step 63 and/or returns to step 61. If the answer to the query in step 61 is "yes", a sensor signal source optionally emits a selected first signal in a selected direction, in step 65. In step 67, a signal sensor, located on the radiotelephone, receives a selected second signal, which may be a result of reflection of the first

20 signal from a nearby object. In step 69, the system measures a signal indicium that represents or corresponds to distance d from the object to the radiotelephone sensor (e.g., signal intensity, temperature, etc.) and estimates the distance d. In step 71, the system compares the distance d with a reference distance d(ref) and determines if d is greater than d(ref).

25 If the answer to the query in step 71 is "yes", the takes at least one of four selected actions, in step 73: (1) the system adjusts the speaker volume and/or the microphone gain of the radiotelephone to its maximum signal level; (2) the system

notifies the radiotelephone user that the user is outside a proximity zone (using a

visually perceptible or audibly perceptible signal, for example) and/or that the

maximum signal level may be inadequate to maintain acceptable audio

communication; (3) the system disables the speaker and/or the microphone until

5   the sensor-head distance is no greater than the reference distance d(ref); and (4)

the system makes no (further) adjustment in speaker volume and/or microphone

gain. If the answer to the query in step 71 is "no", the system, in step 75, uses at

least one of two distance comparison indicia, the difference, d(ref) - d, and the

ratio, d/d(ref), to automatically determine and implement an adjustment in speaker

10   volume and/or in microphone gain for the radiotelephone, to an audio signal level

that is no greater than the maximum signal level. If the sensor used here is

temperature, capacitive response or another signal that is provided by the object

itself, step 65 is deleted here. The speaker volume adjustment and the microphone

gain adjustment may be proportional to each other, or these two adjustments may

15   be made independently of each other, based on the separate audio characteristics

of a speaker and a microphone.

Figure 8 is a schematic view of a radiotelephone 80 powered by a battery or

other power source. The radiotelephone 80 includes an a signal receiver 81 for

audio and/or data signals, connected to an antenna 82, to receive signals from an

20   audio signal source and/or a data signal source, spaced apart from the

radiotelephone, and a signal transmitter 83, also connected to the antenna, to

transmit audio and/or data signals to an intended recipient. The radiotelephone 80

includes a display sub-system 84, to display alphanumeric text including telephone

numbers, and a keypad 85 with alphanumeric keys to enter a called party's

25   telephone number and other alphanumeric characters. The radiotelephone 80

includes a control processor 85, optionally including a memory unit, to control the

processing of audio and/or data signals received from or to be sent to the antenna

82. The radiotelephone 80 also includes a speaker 86 and a microphone 87 whose signals are also processed by the control processor. A portable radiotelephone also includes a battery or other source of electrical power for the other components. The radiotelephone 80 includes one or more proximity signal sources 89 and one or more proximity signal sensors 90, located on or adjacent to the radiotelephone housing.

Optionally, the minimum speaker volume $V_s(min)$, the maximum speaker volume $V_s(max)$, the minimum microphone gain $G_m(min)$ and/or the maximum microphone gain $G_m(max)$ is adjustable by the user to fit the user's own auditory characteristics. A radiotelephone user that is partly hearing-impaired will choose higher values for $V_s(min)$ and $V_s(max)$. A radiotelephone user whose voice is much stronger than average will choose smaller values for $G_m(min)$ and $G_m(max)$. Figures 9 and 10 graphically illustrate how the speaker volume V_s and the microphone gain G_m may be caused to vary between their respective minimum and maximum values, as a function of estimated distance d from the signal sensor to an object (e.g., radiotelephone user), as d varies from $d(min) = 0$ to a maximum distance $d(max)$ that may be a measure of the proximity zone. The speaker volume $V_s(d)$ (and, similarly, the microphone gain $G_m(d)$) may "plateau" at a relatively small positive number $V_{s0} = V_s(min)$ for distances d less than a minimum reference distance $d(ref;min) > 0$, as shown in Figures 9 and 10. Otherwise, $d(ref;min)$ may be set equal to 0. The quantities $V_s(d)$ and $G_m(d)$ increase monotonically, preferably strictly monotonically, with increasing radiotelephone-user distance d beyond $d(ref;min)$ up to a distance $d(ref;max)$ that corresponds to a radius of the proximity zone.

Preferably, distance estimates provided by two or more sensors, or by two or more sensors of different types, are used in combination to determine a best estimate of the user-radiotelephone distance.